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Heavy rainfalls and extensive landslides occurred in Basilicata, Southern Italy, in 1976

M. Polemio
CNR-CERIST, Bari, Italy

F. Sdao
Engineering Faculty, Basilicata University, Potenza, Italy

ABSTRACT: In the past decades, huge proneness to landslides have taken place after heavy and relentless rainfalls and caused severe damage to a number of urban centres and facilities in Basilicata (Southern Italy).The unexpected plentiful rain fallen over the course of the year contributed to the severe hydrogeological crisis which struck Basilicata in 1976. Large floods and extensive deep-seated landslides were repeatedly reported in the area. For the purpose of this paper, some great landslides that occurred late in 1976 were selected. Precipitation records were compared to average rainfalls measured at the same location. For one of the landslides under examination, a statistical and hydrologic model was used in order to assess the recurrence interval of cumulative rainfalls of varying duration.The amount of precipitation in 1976 is particularly striking in terms of extent of the area covered and duration of heavy rainfall , both higher than average, and intensity of rainfall of a given duration.

RESUME: Ces dernières années, à la suite de pluies intenses et prolongées, des éboulements importants se sont produits et se sont rendus responsables de dommages graves en Basilicata (Italie meridionel). Il en ressort le caractère inhabituel des pluies tombées qui ont contribué à provoquer la vaste crise hydrogéologique de l'automne 1976, qui s'est vérifiée en Basilicata. Cette crise s'est manifestée par des inondations de taille et de nombreux éboulis, oux aussi importants par leur extension et leur profondeur. On a sélectionné certains des éboulis les plus importants qui se sont vérifiés fin 1976. Le caractère exceptionnel des pluies tombées dans la région tout au long de l'année a été évalué par rapport aux valeurs moyennes caractéristiques. Le pluies de l'année 1976 s'avèrent enfin exceptionnelles, que ce soit par l'extension du territoire intéressé par les pluies, bien supérieures à la moyenne, par la durée notable, durant l'année, de pluies supérieures à la moyenne, ou par le caractère exceptionnel des pluies d'une durée spécifique.

1 INTRODUCTION

The extensive and severe landslides which have taken place in Basilicata (Southern Italy) in the last decades have gravely damaged the urbanised and developing zones. The mass movements were commonly the result of rather ordinary rainfalls, as was the case in November 1959, in winter 1972, in March 1973, in autumn 1976 and in December 1985 (Sdao et al. 1996; Polemio & Sdao 1996a,b,c; Polemio & Sdao 1997; Catenacci 1993).

This paper focuses on the extensive and severe proneness to landslides occurred in Basilicata in autumn 1976, mainly throughout November and December. Landslides of different type and extent were originated in the eastern and southern part of the region. Some of them struck many urban areas and produced severe damage (Fig. 1).

The role of rainfall in Basilicata in autumn 1976 was thoroughly investigated. Emphasis was put on the rather unprecedented heavy precipitations which occurred throughout the year and their contribution to determining the corresponding hydrogeological crisis. The extremely heavy precipitation fallen over the region throughout the year was measured by some rain-gauge stations. Precipitation records were compared to average rainfalls measured at the same location. For one of the landslides under examination, a statistical and hydrologic model was used in order to assess the recurrence interval of cumulative rainfalls of varying duration.

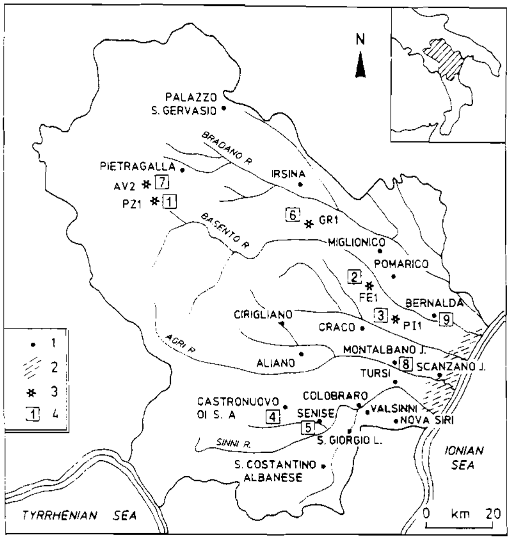

Fig. 1. Basilicata: 1) Location of the urban centres struck by landslides after 1976 rainfalls. 2) Areas where rivers burst theirs banks and flooded the surrounding countryside. 3) Selected landslides. 4) Rain-gauge stations.

2 THE 1976 HYDROGEOLOGICAL CRISIS AND RELATED MASS MOVEMENTS

Late in autumn 1976, the whole Basilicata region was involved by heavy and relentless rainfall with daily precipitation amounts of some hundreds of millimetres. Rainfalls were particularly intense along the eastern and Ionian coastline (on November 5, some 130 mm of rain were recorded at Montalbano Ionico).

Along the Ionian coast, in the vicinity of Nova Siri, Pisticci, Scanzano Ionico and not far from Bernalda, the main rivers (Basento, Agri, Sinni) burst their banks flooding hundreds of hectares of arable land and causing severe damage (Fig. 1). Great damage was produced by the overflowing of the Basento River. Flood events of various severity and magnitude were recorded in a number of urban centres.

But most devastating were the widespread and massive landslides unleashed by the heavy rains which caused considerable damage to property and crops. Instability phenomena affected most of the region, both the Apennine mountains and the areas limited by the Bradanic Foreland.

Mass movements affected most of the geologic formations found in the montainous and hilly areas of Basilicata, namely the Plio-Pleistocene soils outcropping in the eastern side of the region (Blue-grey Clays, retrogressive sandy conglomerate successions) and the rather structurally complex formations of predominantly argillaceous and highly tectonised flysch facies (Varicoloured Clays, Red Flysch and Flysch of Lagonegro).

Most slides were rototranslational or translational slides and earthflows resulting wholly or in part from the reactivation of pre-existing slide masses. First-time slides were rarely reported.

The extent of the affected area and damage produced to a number of urban centres and facilities testifies to the severity of the phenomenon. Many urban centres were gravely damaged by the landslides triggered in autumn 1976 (Fig. 1). Landslides were blamed for damage caused to many towns, Colobraro, Avigliano, Pisticci, Aliano and Grassano to name a few. The Casaleni FE1 landslide, which was reactivated east of Ferrandina,

Table 1. Investigated landslides.

Landslide	Data		Landslide type	Length, width, thickness (m)	Involved geology formation
PI1	21	Nov	Rototranslational slide - earthflow	≅1800, 100÷250, 20÷25	Pleistocenic sands and blue Clays
AV2		Nov	Rototranslational slide	250, 150, 13÷16	Pliocenic sands
GR1		Nov	Rototranslational slide	300, 100÷250, 30÷40	Pleistocenic blue Clays
PZ1	5	Dic	Rotational slide - earthflow	2700, 100÷250, not known	Pliocenic conglomerates and Varicoloured Clays (Cretacico – Oligocene).
FE1		Nov	Rotational slide	1000, 150÷600, not know	Pleistocenic clayey sands and blue Clays

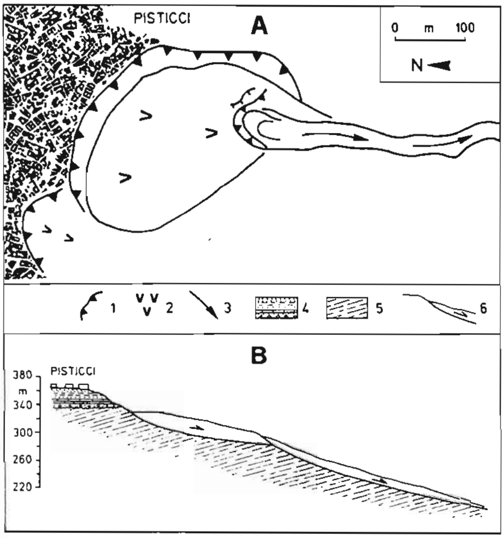

Fig. 2. PI1 Landslide (Pisticci). A) Geomorphological map: 1) Scarp of the lanslide, 2) rototranslational slide, 3) earthflow, B) landslide geomorphological section: 4) Pleistocenic yellow sands; 5) Blue Clays; 6) landslide body. (after Guerricchio & Melidoro 1979, simplified).

is described in Table 1 (FE1 landslide) (Del Prete et al. 1992). Five landslides triggered by the heavy rains were selected (Fig. 1 Table 1): the PI1 in the Croci neighbourhood (Pisticci) (Guerricchio & Melidoro 1979); the AV2 in the Gianturco neighbourhood (Avigliano) (Polemio & Sdao 1996 b); the GR1 at Grassano (Cotecchia & Del Prete 1986); the PZ1 or Giarrossa landslide on the outskirts of Potenza (Lazzari, 1977; Guida & Iaccarino 1991) the FE1 at Ferrandina (Del Prete et al. 1992). The geomorphology and evolutionary pattern of the selected landslides were known and precipitation records were available.

The PI1 landslide at Pisticci. During the night between November 20 and 21, 1976, a disastrous landslide swept away the Croci neighbouhood in Pisticci, destroying tens of homes and causing considerable damage to the roads (Fig. 2, Table 1). The landslide, preceded by a number of forewarning signs (Guerricchio & Melidoro 1979), occurred in an area with a history of similar mass movements. The Pleistocene succession affected by the landslide is made up of blue-grey clays and marls (Formation of Blue-Grey Clays) and yellow sands interbedded with calcarenite (deposits of sea terraces). The main scarp, more than 25 m high, which swept away houses and roads, is found in the sandy formation, whereas the slide surface interest the underlying clayey formation.

The AV2 landslide in the Gianturco neighbourhood at Avigliano. The Avigliano relief, shaped in the sandy conglomerate soil of the Middle Pliocene era, is largely affected by significant mass movements which are periodically renewed wholly or in part by rainfalls, earthquakes and human agency (Del Prete et al., 1992; Polemio & Sdao, 1996b). Figure 3 reports, among the many landslides striking the urban area, the ones which are most likely to be reactivated by rainfalls (Polemio & Sdao 1996b). The landslide occurred in the Gianturco neighbourhood (Table 1) corresponds to AV2 in Figure 3. Over the past 70 years, this ancient landslide has experienced at least 11 reactivations unleashed by rainfalls which were not necessarily heavy. However, great damage was repeatedly produced to urban facilities, houses and roads by this slope movement of rototraslational nature. The slide mass, which involved Pliocene sandy soils and the underlying debris and backfill, exhibits decayed and hardly recognisable boundaries.

The GR1 landslide at Grassano. The Grassano relief consists of a retrogressive Pleistocene succession originated during the sedimentary cycle of the Fossa Bradanica, made up of Blue-grey Clays, sands and conglomerates (Cotecchia & Del Prete 1986).

The old town centre lies on an extensive deep-seated rototranslational slide, consisting of three slide units identified by the corresponding scarps (Cotecchia & Del Prete 1986) (Fig. 4, Table 1). The slide mass, affected by a visible furrow erosion, has been repeatedly reactivated in the past. The last reactivation occurred after the earthquake on November 23, 1980. In November 1976, the lower portion of the landslide (Fig. 4) was subject to intense activity which led to the destruction of the nearby facilities and cemetery.

The PZ1 landslide at Giarrossa. This old and large landslide, ascribed to a rotational slide – earthflow type, has suffered frequent partial or total reactivations (Lazzari 1977; Guida & Iaccarino 1991), the most recent of which followed the November 1980 earthquake. Some previous reactivations dated back to 1950s.
On December 5, 1976, the landslide was totally reactivated - from the main scarp down to the underlying debris layer - and flattened some isolated huts and roads (Fig. 5, Table 1). A suburb, Ravizzone, was evacuated. In the upper part, the landslide affected the outcropping Pliocene sandy

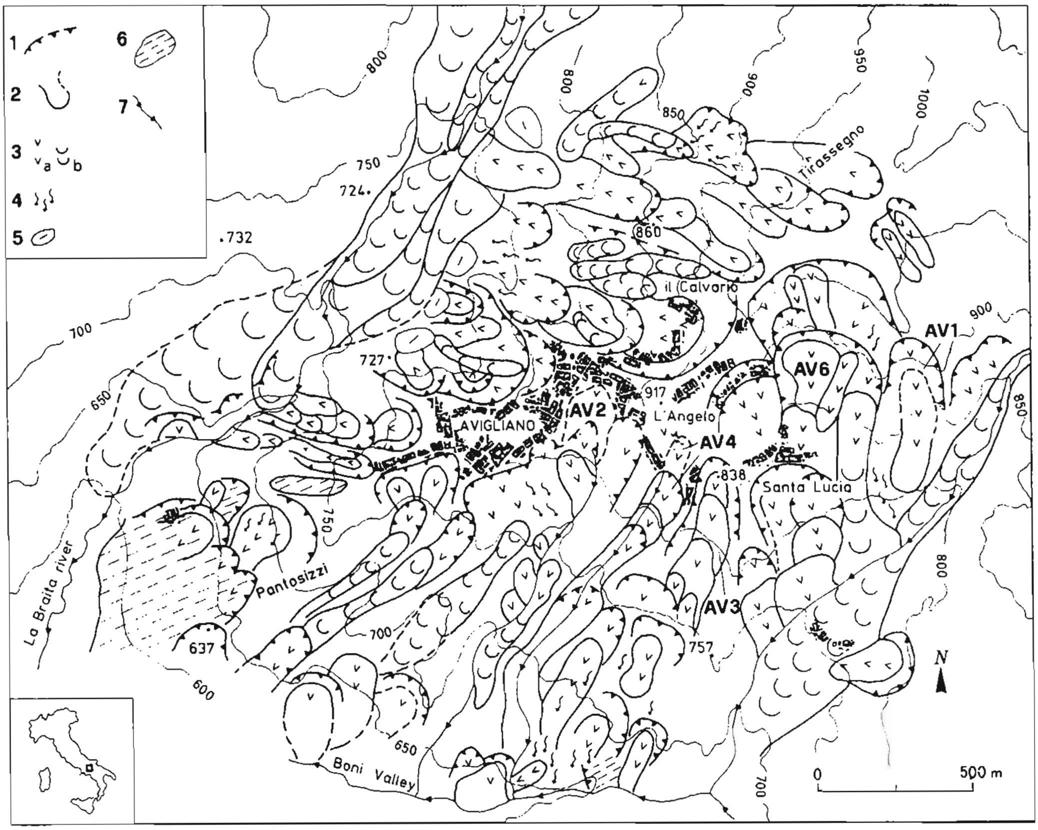

Fig. 3. Avigliano landslides. Geomorphological map. 1) Main scarp of the landslide; hatched where decayed or uncertain; 2) boundary of the mass slide, hatched where decayed or uncertain; 3) rototranslational slide (a), earthflow (b); 4) area subject to intense creeping; 5) landslide-related morphological depression; 6) landsliding area; 7) main drainage line. The investigated landslide is AV 2.

conglomerates of the Ariano Unit, whereas in the middle and lower portion it involved the structurally complex clayey-marly soils of the Varicoloured Clays (Cretaceous - Oligocene). The slide mass was 2,500 m long, 100-250 m large and about ten metres deep. The central part filled a pre-existing watershed, whereas the toe material blocked the bed of the Fiumara Malamogliera, thereby splitting it into two channels that currently border the slide mass. The initial failure was characterised by extremely high displacement velocities (Lazzari 1977). Then, the movement gradually slowed down.

3 AVERAGE RAINFALL RATE AND RAINFALL INTENSITY IN 1976

Nine rain-gauge stations, operational for at least 50 years during the present century, were selected (Fig. 1, Table 2). Due to the influence of west winds blowing from the Tyrrhenian Sea and the morphological impact of the Apennine mountains, rainfall rate generally decreases from north-west to south-east, along the main river valleys debouching into the Ionian sea. At the selected stations, the average annual rainfall depth ranges between 619 mm and 986 mm (Table 2).

In order to assess the rainfall rate at each station, the monthly average rainfall depth was estimated as a percentage of the annual one. The estimated amount of precipitation was found to be typical of maritime environments, with the minimum recorded between July and August and the maximum between November and December. Slight per cent variations were observed among the stations and the average rainfall rate was inferred (Table 2).

The rainfalls recorded in 1976 were significantly higher than average at all stations. The annual

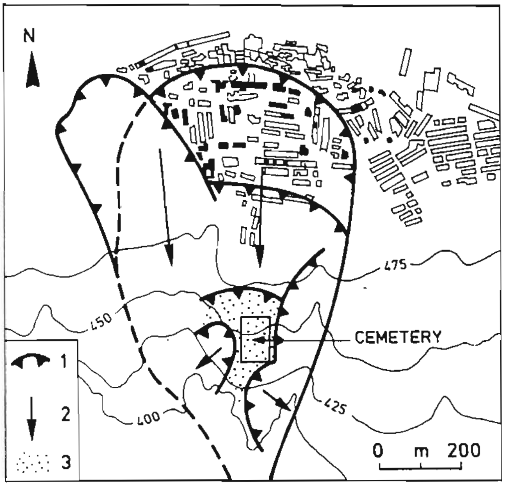

Fig. 4. GR1 landslide at Grassano - (after Cotecchia & Del Prete, 1986, simplified). 1) Main scarp of the landslide; 2) rototranslational slide; 3) lower portion of huge landslide body reactivated in November 1976.

Starting from November and moving backward, cumulative rainfalls with one-month increments were calculated (Table 2). Hence, the cumulative rainfalls were determined per station, as a percentage of the averaged cumulative rains having the same duration. These values are not reported for the sake of brevity. However, a brief discussion follows.

All the cumulative rainfalls recorded by the stations were higher than average with peak values corresponding to rainfall durations of one to two months or six to seven months (282% and 252% higher than average for one and two months and 215% and 217% higher than average for five and six months).

Bernalda station recorded the heaviest rain. The cumulative value measured during 1, 2 and 3 months decreases from 351% to 274% of the mean value. Due to 143 mm of rain fallen in August - a month which usually produces little rain - the cumulative rain calculated over 4 months (from August to November) is 300% higher than the mean value.

rainfall depth in 1976 ranges between 831 and 1293 mm. The same variable, taken as a percentage of the annual mean of each station, ranged between the minimum recorded at station 5 (125.2%) and the maximum at station 6 (162.7%).

The monthly rainfall depth per station in 1976 was given as a percentage of the average rainfall measured throughout the observation period.

The first three months of the year (January-March) exhibited less precipitation than average. The monthly rainfall rate averaged at the nine stations in the first three months was 40%, 79% and 79%, respectively.

A period of rainfalls exceeding the average started in April and lasted till the first decade of December. Even the summer months, which generally exhibit meager precipitation, recorded significant monthly rates, 200% higher than the average of the nine selected stations. September was the only exception. At all stations, values below average were recorded for 30 days.

Following the plentiful rain produced from April to August and the new wave of precipitation resuming in October, the conditions were ripe for both infiltration and run-off.

Since flood events and slope instability phenomena occurred end of November, beginning of December, a month for which no rainfall records are available, the end of November was taken as reference time.

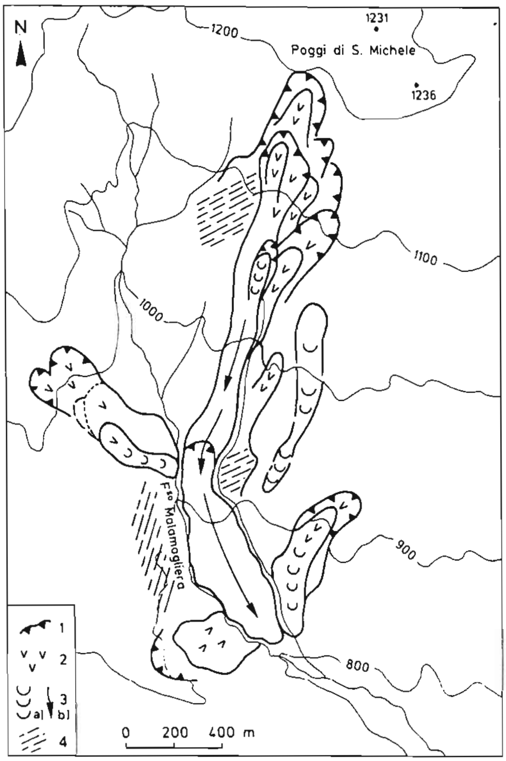

Fig. 5. Giarrossa landslide. 1) Main scarp of the landslide; 2) rotational slide; 3) Secondary (a) and principal earthflow; 4) landsliding area.

Table 2. Yearly mean rainfall and regime, years of data and 1976 rainfall. (*) Out of order during December.

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGU	SEP	OCT	NOV	DIC
Mean regime %	11.6	9.8	9.2	7.6	7.1	5.4	3.7	3.7	6.7	9.8	12.8	12.6

GAUGE		**CUMULATIVE RAINFALL (mm) FROM 1 TO 11 MONTHS (m) BEFORE THE END OF NOVEMBER 1976**											**YEARLY RAINFALL (mm)**	
N.	**LOCATION (YEARS)**	**11 m**	**10 m**	**9 m**	**8 m**	**7 m**	**6 m**	**5 m**	**4 m**	**3 m**	**2 m**	**1 m**	**1976**	**MEAN**
1	S.N. Avigliano (56)	869	820	784	723	659	561	493	396	334	306	212	960	715.5
2	Ferrandina (47)	772	752	712	662	606	539	461	419	351	339	211	831	578.0
3	Pisticci (66)	833	815	759	711	659	590	477	412	341	326	204	904	619.0
4	Roccanova (54)	837	804	755	689	623	562	495	483	426	415	261	969	706.3
5	Senise (57)	852	814	727	685	625	570	485	464	412	399	241	979	782.2
6	Calciano (54)	1021	989	884	847	751	669	538	455	410	408	281	1123	690.3
7	Avigliano (61)	1156	1063	1032	937	811	677	588	507	458	398	281	1293	985.8
8	Montalbano (50)	868	844	786	744	709	656	603	548	474	461	288	964	672.0
9	Bernalda (57)	1069	1064	1048	1019	955	911	828	669	526	506	280	(*) >1069	630.7

Precipitation fallen at the stations 8, 6, 2 and 4 exhibits similar characteristics, though to a limited extent.

In 1976, stations 1, 3, 5 and 7 recorded less significant amounts of precipitation, though equally unusual as shown by a careful analysis of station 7. Rainfalls fallen in November at the above three stations ranged between 227% and 235% of the relative mean.

The above discussion shows that, late in 1976, Basilicata was struck by unprecedented rainfalls of striking intensity, duration, recurrence and/or extent. The combination of these factors resulted in a severe and prolonged hydrogeological crisis which triggered flooding and landslides.

When focusing on the instability phenomena of the investigated slopes, the following considerations can be drawn.

As to the PZ1 landslide, the rainfalls recorded at the nearby station 1 proved extremely heavy only in July (absolute peak per month/station) and in November (second value in decreasing order per station/month). In the remaining months, prior to the end of November, precipitation was higher than average, though not outstanding.

As to the FE1 landslide, monthly rainfalls were high in August (absolute peak per month/station), in October (third value in decreasing order) and in November (second value in decreasing order). Note that rainfalls fallen before the landslide are by no means ordinary.

As to the PI1 landslide, the monthly rainfalls in 1976 were not surprisingly heavy, not even in the last months of the year. *I.e.* The precipitation in November (204 mm) accounts for the 4th historical value in decreasing order per station/month.

As to station 6, located in the vicinity of the GR1 landslide, and station 7, which is referred to when discussing the AV2 landslide, in November the maximum precipitation ever fallen was recorded per station/month. The same statistical records were provided by stations 4, 7 and 8. Significant values were recorded at stations 5 and 9 where, in October and November, the second value in decreasing order was observed.

The key role of rainfalls in triggering the widespread 1976 landslides is supported by the results of a hydrological and statistical research conducted by the authors. The method was simple and had already been used by the authors (Polemio 1997, Polemio & Sdao 1996a). It was applied to the investigation of the Avigliano landslides (Polemio & Sdao 1996b), namely the AV2 landslide, which is reactivated every 14 years. Cumulative rainfalls with varying duration (1, 5, 10, 20, 30, 60, 90, 120 and 180 days) were assessed on a daily basis. The research showed that the AV2 landslide which took place in 1976 was the result of a 30-day cumulative precipitation with a recurrence interval of 29 years.

This result obtained after a lengthy and troublesome statistical-hydrological analysis corresponds to a station where rainfalls were not somewhat extraordinary. Hence, the Avigliano landslide provides evidence of the contributing role of precipitation in triggering slope instability in 1976.

4 CONCLUSIONS

The amount of precipitation fallen in 1976 is particularly striking in terms of extent of the area covered and duration of heavy rainfall , both higher than average, and intensity of rainfall of a given duration.

The combined characteristics of such precipitation resulted in a severe and prolonged hydrogeological crisis characterised by flooding and landslides.

The role played by rainfalls in triggering the 1976 mass movements was also discussed.

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